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Geothermal Resource Assessment in Small Volcanic Islands: The case of the Aeolian Archipelago and the IRGIE Project

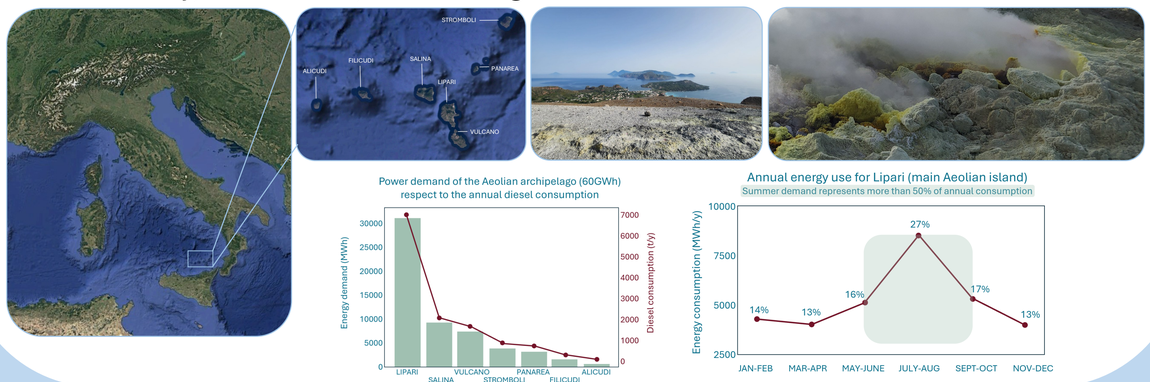
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IRGIE
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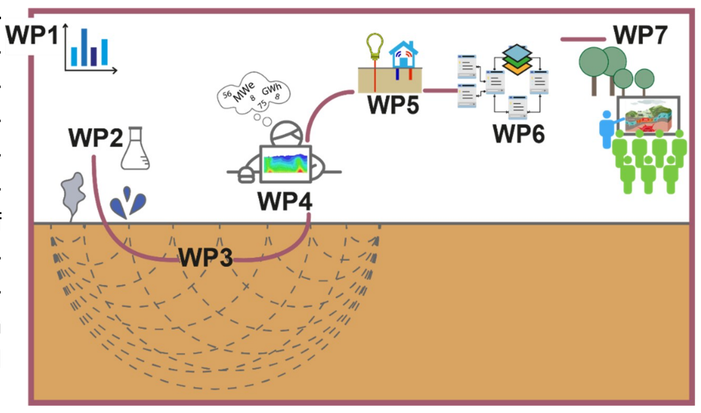
INTRODUCTION

Small islands face significant energy challenges due to geographic isolation and lack of infrastructure. This is especially relevant for **volcanic islands** such as the **Aeolian Archipelago**, located in the **Southern Tyrrhenian Sea (Italy)** and constituted of seven islands (Alicudi, Filicudi, Salina, Lipari, Vulcano, Panarea and Stromboli). Currently, these islands are not connected to the mainland electrical grid and the electricity is primarily generated by small diesel plants. As a result, the sustainability index remains below 30%, underlining the urgent need to harness local renewable energy sources. The **IRGIE project** (Inventory of Geothermal Resources of the Aeolian Islands, 2023–2026), led by **INGV** and funded by the *Regione Siciliana,* aims to identify, characterize, and assess geothermal resources across the Aeolian islands.



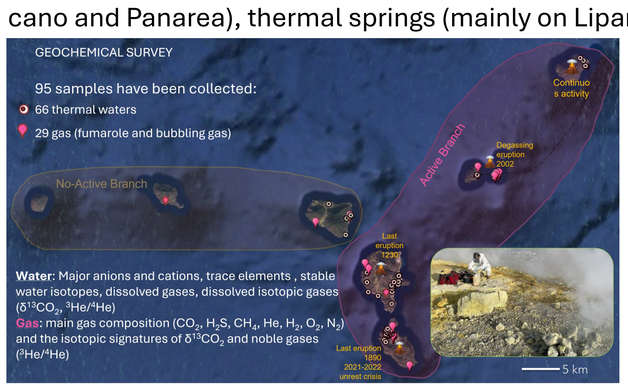
METHODS

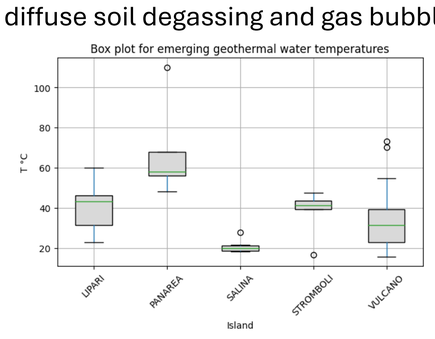
The project covers the first stage of a geothermal exploration program and focuses on the identification and characterization of geothermal systems across the Aeolian islands starting from surficial geochemical and geophysical **surveys**. The project adopts a strongly **multidisciplinary approach**, integrating geochemical (**WP2**) and geophysical data (**WP3**) to support numerical modelling (**WP4**), technological aspect (**WP5**), data infrastructure (**WP6**), and the analysis and dissemination of social aspects related to geothermal energy (**WP7**). The integration of geochemical and geophysical datasets supports the construction of conceptual geothermal models and reservoir geometry useful to estimate the theoretical and technical geothermal potential. Another key component of IRGIE project is its outreach programme, encompassing the creation of tailored dissemination tools to promote knowledge and awareness of geothermal energy.

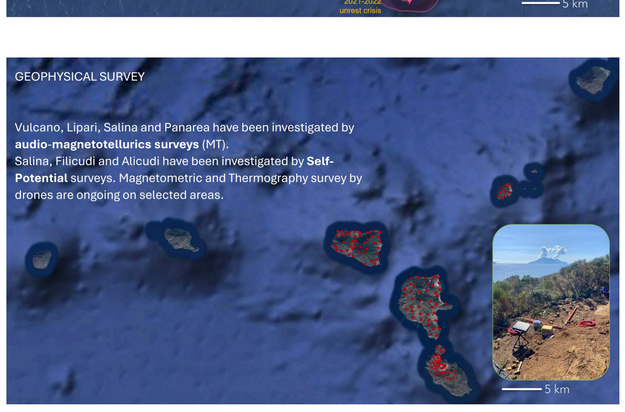


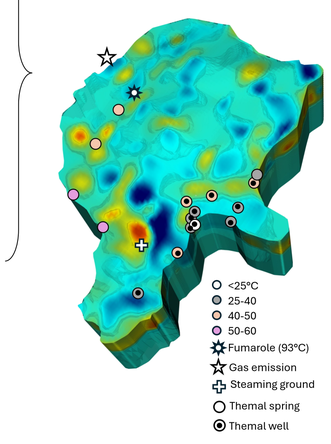
RESULTS

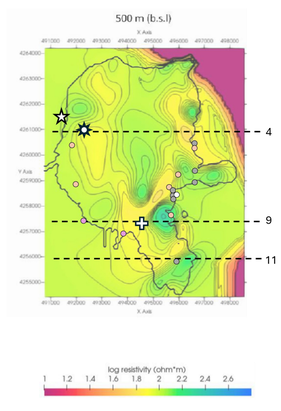
From a volcanic perspective, the Aeolian Archipelago can be subdivided into two main sectors: an inactive volcanic domain extending westward from Salina, and an active volcanic alignment trending NE–SW, including the islands of Stromboli, Panarea, Lipari and Vulcano. The active branch is characterized by widespread surface manifestations, including fumaroles (particularly at Vulcano and Panarea), thermal springs (mainly on Lipari), diffuse soil degassing and gas bubbling. **Vulcano** is characterized by numerous thermal wells in the Vulcano Porto area, where water temperatures range from ~20 to 75 °C, high-temperature fumaroles (100–300 °C), diffuse soil degassing, submarine gas emissions are also present. **Lipari** hosts thermal springs on the western side of the island and wells on the eastern side, with temperatures between ~22 and 60 °C, submarine gas bubbling and a fumarolic gas emission at Cava di Caolino (93 °C). **Panarea** shows onshore thermal wells and intense submarine hydrothermal manifestations, with sampled temperatures ranging from ~48 to 110 °C. **Stromboli** is characterized by thermal wells with temperatures between ~39 and 48 °C. Fluids mainly display Cl–SO_4 and Na–Cl chemical facies, reflecting strong gas–water–rock interaction and mixing among meteoric, marine, deep hydrothermal fluids and superheated steam. **Salina, Filicudi** and **Alicudi** show only low-temperature waters dominated by meteoric and marine mixing.







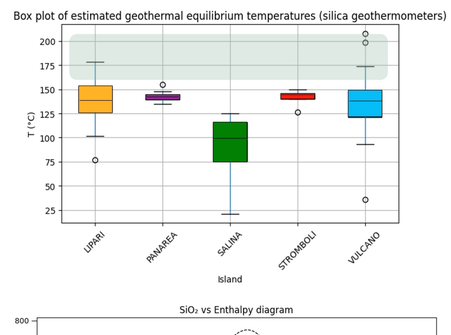


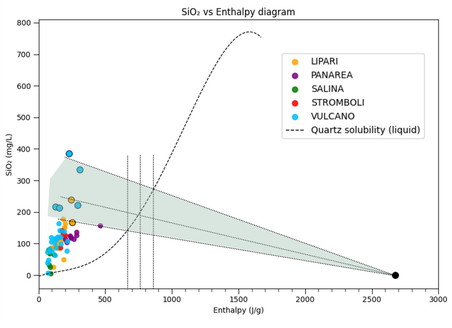


Audiomagnetotelluric (AMT) surveys were carried out to characterize subsurface resistivity structures and to delineate the volume and depth extent of potential geothermal reservoirs. At the scale of the archipelago, low-resistivity anomalies identified show a good spatial correspondence with areas characterized by active hydrothermal manifestations. At Lipari, 3D AMT modeling reveals shallow low-resistivity volumes (<30 Ω·m) mainly concentrated in the western and southern sectors of the island. These conductive bodies, emerging at depths of ~500m b.s.l., are interpreted as hydrothermally altered and zones hosting geothermal reservoirs.

DISCUSSION

Estimating the temperature of geothermal reservoirs represents a fundamental first step in the assessment of geothermal potential. In this framework, **silica geothermometers** were applied to provide first-order estimates of equilibrium temperatures. However, their application may be significantly affected by boiling and mixing processes during fluid ascent, particularly at Vulcano, Lipari, Panarea and Stromboli. To account for these effects, the **SiO_2–enthalpy** diagram was used. This approach allows the reconstruction of the enthalpy of the deep geothermal fluid prior to boiling, leading to more reliable estimates of equilibrium temperatures. Here we **focus** in particular **on** the islands of **Lipari and Vulcano**, which show a stronger onshore geothermal signature. In contrast, Salina, Filicudi and Alicudi do not display clear evidence of active hydrothermal systems. Stromboli, despite its high heat input, is not discussed in detail because of persistent volcanic activity and its limited areal extent. Similarly, at Panarea, the most significant geothermal systems is located offshore, with only marginal onshore expressions. At **Lipari**, corrected silica-based temperatures indicate equilibrium values of **~160–180 °C** for samples showing the strongest geothermal input, mainly located in the central-western sector of the island, suggesting the presence of moderate-high-temperature reservoirs. At **Vulcano**, corrected temperatures range between **180 and 220 °C**, particularly in the Vulcano Porto area, pointing to a more thermally mature geothermal system. These temperature ranges are consistent with independent estimates obtained from multicomponent geothermometry. For both islands, geophysical surveys highlight the presence of **shallow geothermal reservoirs at depths <600 m** (see poster by Maffucci R. et al.).

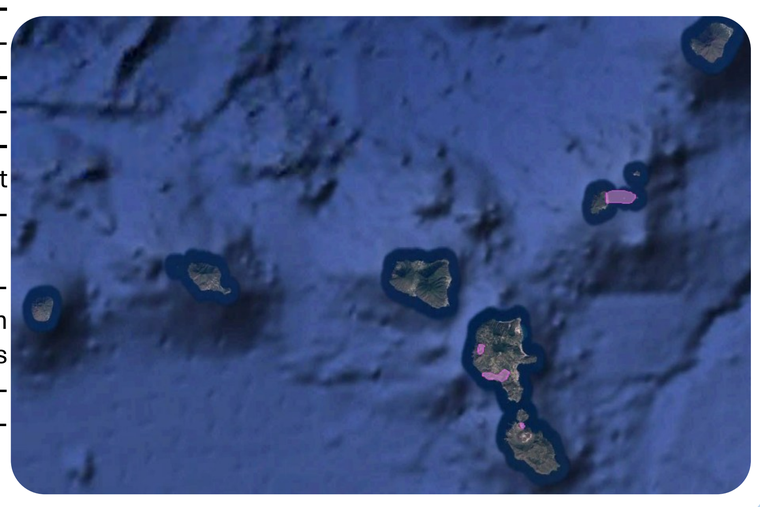




CONCLUSION

The IRGIE project provides the first integrated geothermal assessment of the Aeolian Archipelago (southern Italy), combining geochemical and geophysical surveys to identify and characterize geothermal systems in a volcanic island setting. The results highlight **Lipari and Vulcano** as the islands with the highest **onshore geothermal vocation.** Silica geothermometers corrected for boiling indicate equilibrium temperatures of approximately **160–180 °C at Lipari** and **180–220 °C at Vulcano**, in agreement with multicomponent geothermometry , for **shallow reservoir (<600 m)**. At **Panarea**, the most significant geothermal system is located **offshore**, with only marginal onshore expressions, while **Salina, Filicudi and Alicudi** do not show evidence of active hydrothermal systems.

The final map summarizes these results by highlighting, in pink, the most interesting areas for future geothermal exploration and modelling in the Aeolian Islands.



Acknowledgements

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Regione Siciliana

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